Elevation changes of ice caps in the Canadian Arctic Archipelago

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[1] Precise repeat airborne laser surveys were conducted over the major ice caps in the Canadian Arctic Archipelago in the spring of 1995 and 2000 in order to measure elevation changes in the region. Our measurements reveal thinning at lower elevations (below 1600 m) on most of the ice caps and glaciers but either very little change or thickening at higher elevations in the ice cap accumulation zones. Recent increases in precipitation in the area can account for the slight thickening where it was observed but not for the thinning at lower elevations. For the northern ice caps on the Queen Elizabeth Islands, thinning was generally <0.5 m yr^{-1}, which is consistent with what would be expected from the warm temperature anomalies in the region for the 5 year period between surveys, and appears to be a continuation of a trend that began in the mid-1980s. Farther south, however, on the Barnes and Penny ice caps on Baffin Island, this thinning was much more pronounced at over 1 m yr^{-1} in the lower elevations. Here temperature anomalies were very small, and the thinning at low elevations far exceeds any associated enhanced ablation. The observations on Barnes, and perhaps Penny, are consistent with the idea that the observed thinning is part of a much longer term deglaciation, as has been previously suggested for Barnes ice cap. On the basis of the regional relationships between elevation and elevation change in our data, the 1995–2000 mass balance for the archipelago is estimated to be -25 km^3 yr^{-1} of ice, which corresponds to a sea level increase of 0.064 mm yr^{-1}. This places it among the more significant sources of eustatic sea level rise, though not as substantial as the Greenland ice sheet, Alaskan glaciers, or the Patagonian ice fields. *INDEX TERMS:* 1640 Global Change: Remote sensing; 1699 Global Change: General or miscellaneous; 1827 Hydrology: Glaciology (1863); 1863 Hydrology: Snow and ice (1827); *KEYWORDS:* ice caps, Arctic, mass balance

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1. Introduction

[2] Glaciers and ice caps outside of Greenland and Antarctica contain enough water to raise sea level by an estimated 0.5 m [*Church et al.*, 2001]. Although their long-term potential contribution to sea level is far less than that of Greenland or Antarctica, their smaller size and more temperate characteristics may make their near-term contributions, estimated at up to 20 cm in the next 100 years [*Church et al.*, 2001], more substantial. Among these ice masses, the Canadian ice caps are of particular importance primarily because they are situated in the Arctic, where the regional-scale positive albedo feedbacks and interactions between ocean, atmosphere, and sea ice are expected to amplify the effects of climate change [*Cubasch et al.*, 2001] and also because, with an area of 152,000 km^2 [*Ommanney*, 2002], they are among the largest of the Arctic glaciers and ice caps. In light of recent observations of the Greenland ice sheet indicating significant thinning in the warmer regions below 2000 m [*Krabill et al.*, 2000] and studies showing significant wastage of Alaskan glaciers [*Arendt et al.*, 2002], understanding the mass balance of other Arctic ice masses is a matter of increasing interest.

[3] In an effort to assess the current mass balance of the major Canadian ice caps, we conducted precise airborne laser surveys in spring of 1995 using NASA's Airborne Topographic Mapper (ATM) on board the NASA P-3 aircraft and repeated these measurements again in spring of 2000 on a commercial Twin Otter platform. The locations of these survey lines are shown in Figure 1. The survey trajectories were designed to cross the broadest and longest portions of the major ice caps, and where possible, they were planned to cover some of the more significant outlet glaciers.

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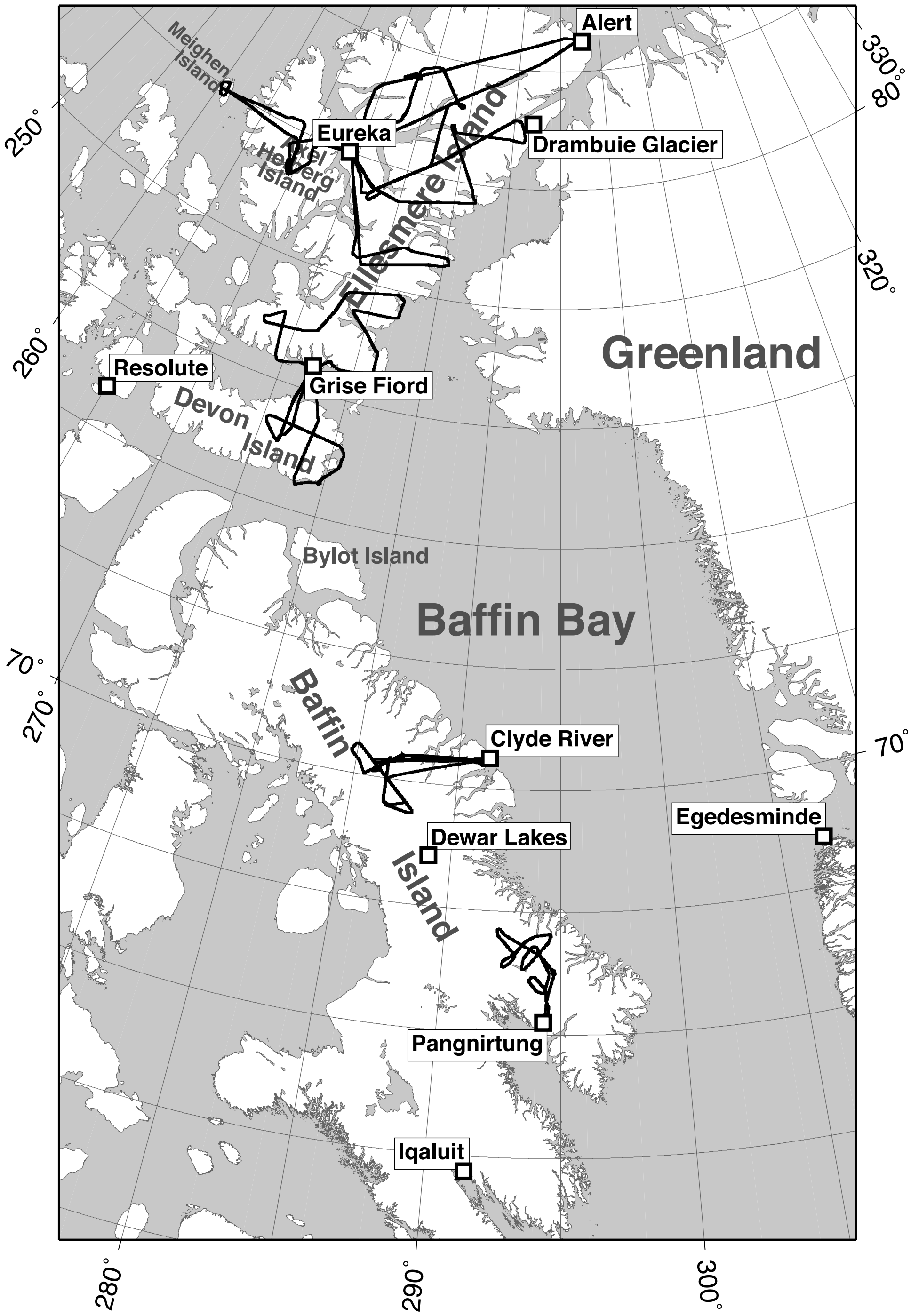

Figure 1. Location map of the 2000 flight lines (repeat surveys of the 1995 lines) in the Canadian Arctic Islands. Flights were conducted out of Pangnirtung, Clyde River, Grise Fiord, and Eureka. Weather station data used in this analysis were from Eureka, Alert, Resolute, Clyde River, Iqaluit, Egedesminde, and Dewar Lakes.

[4] The ATM combines precise ranging capability with Global Positioning System (GPS) techniques to retrieve surface elevation to a root-mean-square error of 10 cm or better [*Krabill et al.*, 1995, 2002]. As such, it provides a valuable tool for measuring changes in the ice cap surface elevations by means of repeat surveys when there is adequate time separation between measurements. The Canadian ice cap campaigns, like those in Greenland, were conducted over a 5 year time interval in an effort to minimize the effects of year-to-year variability.

[5] The surveys are designed to provide a spatially broad assessment of ice cap thickening and thinning rates over the 5 year time interval. These complement the in situ measurements of accumulation and mass balance that have been ongoing as part of the Canadian glaciology program [*Koerner*, 2002]. These in situ observations, while local in nature, span a period of more than 4 decades in some cases and provide a historical context for some specific locations.